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GUIDE FOR THE SELECTION AND USE OF PIEZOELECTRIC CERAMIC MATERIALS AND ELEMENTS

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GUIDE FOR THE SELECTION AND USE OF PIEZOELECTRIC CERAMIC MATERIALS AND ELEMENTS

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(*Continued from page* 1)

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Indian Standard

GUIDE FOR THE SELECTION AND USE OF PIEZOELECTRIC CERAMIC MATERIALS AND ELEMENTS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 28 September 1984, after the draft finalized by the Piezoelectric Devices for Frequency Control and Selection Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The object of this standard is to provide a guidance for the use of piezoelectric ceramic materials to their best advantage.

1. SCOPE

1.1 This standard deals with the guidance which will help the user to extend the useful and accurate life of the material by ensuring that it is selected and handled correctly during the fabrication stages.

2. TERMINOLOGY

2.1 The terms and definitions given in IS : 1885 (Part 44) - 1978*, and IS : 11014 (Part 1) - 1984† shall apply.

3. PIEZOELECTRIC CERAMIC MATERIALS

3.1 These materials are manufactured employing usual ceramic techniques. Raw materials, in powder form are homogenously mixed and milled to required particle size, calcined, pressed or extruded in the desired shape, sintered, electroded and finally poled.

3.2 Shapes and dimensions of piezoelectric ceramic materials depend on the dies used for pressing or for the extruding. The properties depend upon the various steps involved in processing, composition and type as mentioned in **4.1**. A good control at the various steps of manufacturing process may ensure homogently in quality and uniformity in shapes and dimensions.

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*Electrotechnical vocabulary : Part 44 Piezoelectric devices.

†Specification for piezoelectric ceramic materials : Part 1 General aspects and methods of measurements.

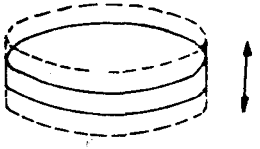

Fig. 1.-Thickness mode in disc

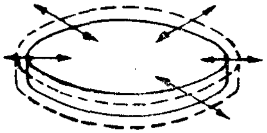

Fig.2. Radial mode in disc

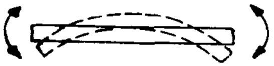

Fig.3. Flexural mode

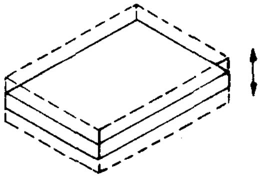

Fig.4. Thickness mode in plate

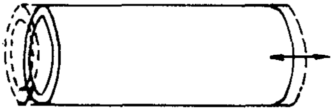

Fig.5. Length mode in tube / Thickness mode in ring.

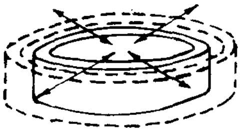

Fig.6. Radial mode in ring / tube.

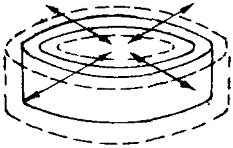

Fig. 7. Wall thickness mode in ring / tube.

FIG. 1 To 7

3.3 The ceramic piezoelectric material have an advantage that the axis of poling can be chosen in any desired direction whereas the crystal axis (equivalent to poling direction of ceramic material) in natural or synthetic crystal may not be chosen arbitrarly.

3.4 As the standard values for size, direction of poling and frequency of piezoelectric ceramic material are carefully chosen to meet the requirement for manufacturing the most common transducers/probes and devices, it is desired that a user should select one of those standard values as specified in this standard. A special order for size, poling direction and frequency will be expensive and will result in a long delivery time.

3.5 The symbols, parameters and units are used associated with ceramic materials elements are given in Table 1.

TABLE 1 SYMBOLS, PARAMETERS AND UNITS

Symbols (1)	Parameters (2)	Units (3)
C^T	Free capacitance (low frequency)	farad (F)
D_m	Mean diameter	meter (m)
ε	Permittivity of free space	$8{\cdot}8542 \times 10^{-12}$ farads/meter
$\varepsilon_{33}{}^T$	Free permittivity of material (low frequency)	farads/meter (F/m)
E	Applied electric field	kilovolt/meter (kV/m)
f_m	Frequency of maximum admittance (minimum impedance)	hertz (Hz)
f_n	Frequency of minimum admittance (maximumimpedance)	hertz (Hz)
$K_{33}{}^T$	Free relative dielectric constant $= \varepsilon_{33}{}^T/\varepsilon_0$	
k_{eff}	Effective coupling factor, $k^2_{eff} = (f^2_n - f^2_m)/f^2_n$	
k_p	Planar coupling factor	
l	Length	meter (m)
N_1	Frequency constant for a ring, $N_1 = (f_m \pi D_m)/2$	hertz - meter (Hz.m)
N_p	Frequency constant planar mode disc, $N_p = (f_m . \text{Diam})$	hertz-meter (Hz.m)
Q_m	Mechanical quality factor, $Q_m = Y_m/(2\pi f_m\ C^T k^2_{eff})$	
ρ	Density	Kilogram/meter^3 (kg/m^3)
σ^E	Poisson's ratio, $\sigma^E = -s^E_{12}/s^E_{11}$	
S^E_{ij}	Elastic compliance at constant electric field	meter^2/newton (m^2/N)
t	Thickness	meter (m)
tan δ	Dielectric loss factor	
w	Width	meter (m)
Y_m	Maximum admittance magnitude	siemens (S) (previously mhos)
Y_n	Minimum admittance magnitude	siemens (S) (previously mhos)

4. TYPE DESIGNATION

4.1 The piezoelectric ceramic materials covered by this standard are type designated as follows:

Material	*Type Designation*	*Remarks*
Barium Titanate Based (BT)	Type 1	Low signal
	Type 2	—
	Type 3	Low signal
Lead Ziromium Titanate Based (ZT)	Type 4	High signal
	Type 5	Low signal
	Type 6	Temperature compensated for filters
	Type 7	Temperature compensated for delay lines
	Type 8	Very high signal

4.1.1 Suitable modifier suffixes may be used to indicate or denote any special property of the piezoelectric ceramic material.

For example, Type 5M modified 'lead ziromium titanate' material having high planar compling coefficient and high dielectric constant.

5. SHAPES AND DIMENSIONS

5.1 Shapes and dimensions of the piezoelectric ceramic elements depend upon the dies used for forming. The final dimensions are adjusted during lapping and sizing after sintering. Dimensions shall be in millimetres with proper tolerance in thickness and out of round, etc.

5.2 Direction of poling and electroded surfaces shall be as follows (*see* Table 2) unless otherwise specified particularly.

TABLE 2 SHAPE AND DIRECTION OF POLING AND ELECTRODED SURFACES

SHAPE	DIRECTION OF POLING	ELECTRODED SURFACE
Disc/plate	Thickness-wise	Surfaces normal to thickness
Ring/tube	Thickness-wise /length-wise	Plane surfaces
Ring/tube	Radially	Curved surfaces

5.3 Dimensions, shapes and frequency shall be within the following tolerances (*see* Table 3).

TABLE 3 PARAMETER WITH TOLERANCES

PARAMETERS	TOLERANCES
Diameter/length/breadth	± 2·5 percent
Frequeucy (up to and including 2 MHz)	± 7 percent
(above 2 MHz)	± 10 percent
Outer diameter	± 2·5 percent
Inner diameter	± 2·5 percent
Flatness	Within 0·2 mm
Squareness	Within 1° *Max*
Thickness taper over diameter	0·08 mm *Max*

5.4 The direction of mode of oscillation for different shapes and desired dimensions which may be firmly made out of ceramic materials covered by this standard may be chosen from Table 4. For various modes of oscillation, only one dimension may be chosen (*see* col 3 of Table 4); other dimensions will depend on the frequency constant and the frequency requirement and as such may not be fixed before hand.

TABLE 4 DIMENSIONS WITH MODES OF OSCILLATION

SHAPE	MODE OF OSCILLATION	DESIRED DIMENSION WHICH MAY BE FIXED	REFERENCE DIAGRAM
Disc	Thickness	Diameter	Fig. 1
Disc	Radial	Thickness	Fig. 2
Disc	Flexural	Either the diameter or thickness	Fig. 3
Plate	Thickness	Length & breadth	Fig. 4
Ring	Thickness	Diameter	Fig. 5
Ring	Radial	Thickness	Fig. 6
Tube	Length	Diameter	Fig. 5
Tube	Radial	Length	Fig. 6
Tube	Wall thickness	Length and one of the O.D. or I.D.	Fig. 7

5.5 Dimensional Tolerance

5.5.1 The dimensional tolerances will be as given in Table 5.

TABLE 5 DIMENSIONAL TOLERANCE

SL No.	CHARACTERISTICS	PERMISSIBLE TOLERANCE
i)	Flatness	0·01 mm for unelectroded surfaces 0·25 mm for electroded surfaces
ii)	Taper over diameter	0·06 mm
iii)	Angularity	Within 2°
iv)	Out of round	Within diameter tolerance
v)	OD	3 percent
vi)	ID	4 percent

6. ELECTRODE AND LEADS

6.1 The electrodes are generally provided with silver coating. Any special electrodes configination may be provided with mutual acceptance of manufacturers and users.

6.2 The leads are not generally provided until and unless it is asked for. In case transducer elements with leads are required the specific position on the transducer shall be clearly marked by drawing alongwith wire gauge number, etc, and also the length of the leads.

6.3 In fixing the leads with the transducer, silver solder shall be used with proper flux.

7. POLING AXIS

7.1 Ceramic piezoelectric materials have an advantage that the axis of poling can be chosen in any desired direction whereas the crystal axis cannot be chosen arbitraily. As such the required direction of polarisation may be mentioned by the purchaser by giving illustrations and drawing for specific applications, if any.

8. AGEING AND THERMAL SHOCK

8.1 In the case of ceramic materials, the material properties vary with ageing conditions-natural or simulated and as a function of time. The manufacturer should therefore stablize the properties by subjecting the materials/elements to appropriate ageing conditions.

> NOTE — Normally 10 days ageing conditions as determined by the manufacturer may be adopted. The small signal parameters such as dielectric constants, the dissipation factors, planar compling coefficient, frequency constant of the ceramic elements shall be measured at three points of times between 10 and 100 days after poling (preferably 10 days, 45 days and 100 days). The 10 days value and ageing rates (excluding tan δ) per time decade from 10 to 100 days shall fall within limits.

9. MARKING

9.1 The piezoelectric ceramic elements shall be marked (+) to identify polarity.

9.2 The carton may have the following information:

- a) Name of the manufacturer,
- b) Type of element,
- c) Configuration of the element,
- d) Power handling capacity of the element,
- e) Resonant frequency,
- f) Static capacitance at 1 KHz,
- g) Safe operating temperature,
- h) Maximum permissible field,
- j) Minimum impedance, and
- k) Recommended prostress.

10. WORKMANSHIP

10.1 The ceramic elements shall be clean and free from chipping and cracks.

10.2 The electrode coating shall be uniform and free from pin holes.

11. ORDERING INFORMATION

11.1 The following information may be needed for ordering:

- a) Material type designation.
- b) Dimensions with tolerance.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Lehgth	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plan angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N=1 kg. m/s^2
Energy	joule	J	1 J=1 N.m
Power	watt	W	1 W=1 J/s
Flux	weber	Wb	1 Wb=1 V.s
Flux density	tesla	T	1 T=1 Wa/m^2
Frequency	hertz	Hz	1 Hz=1 c/s (s^{-1})
Electric conductance	siemens	S	1 S=1 A/V
Electromotive force	volt	V	1 V=1 W/A
Pressure, stress	pascal	Pa	1 Pa=1 N/m^2